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Essential Elements of a Production Readiness Review in DoD Major Capability Acquisition

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Purpose

The purpose of this paper is to present the Essential Elements of a Production Readiness Review (PRR). To accomplish this, we developed the eight Essential Elements of a PRR, including the criteria and metrics for each element. These elements address all of the exit criteria for the Engineering and Manufacturing Development (EMD) Phase, all of the review topics for the Milestone C review, and they are consistent with the requirements from IEEE 15288.2 for a PRR.

In the process of determining these Essential Elements, this paper will also demonstrate that a Manufacturing Readiness Assessment (MRA) is not sufficient as the final program review prior to a Milestone C decision.

Introduction

A PRR is conducted as the final program review prior to the Milestone Decision Authority (MDA) review in which the decision to proceed to **production** is made[1]. A PRR evaluates the full, production-configured system to determine if it correctly and completely implements **all** system requirements. According to the *Systems Engineering Guide,* §3.7*, t*he system PRR should provide evidence that the system can be manufactured with acceptable risk and no breaches in cost, schedule, or performance thresholds. The PRR should also consider what production systems should be retained to sustain and maintain the system through its life cycle.[2]

The information presented in this paper is focused on the Adaptive Acquisition Framework (AAF) pathway for Major Capability Acquisition (MCA), as described and specified by DoDI 5000.85, *Major Capability Acquisitions*. DoDI 5000.85, §3.11 and §3.12 include the content of the EMD phase exit criteria and the Milestone C review topics to begin "production"; however, these sections do not call for a technical review before Milestone C. On the other hand, according to and DoDI 5000.88, *Engineering of Defense Systems*[3], the Program Manager **will** conduct system level reviews, including the PRR.[4] The guidance for conducting a PRR is found in the *Systems Engineering Guidebook,* Feb 2022, which references IEEE 15288.2 as the source.

Prior to the AAF, programs utilized the published DoD Checklists which were tools for conducting reviews. The PRR checklist, "Systems Engineering for Mission Success", from 2013 includes as part of the PRR the following major areas:

- Engineering and Product Design
- Materials and Purchased Parts
- Industrial Resources

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[1] IEEE 15288.2, §5.10.3, and DoDI 5000.88, §3.5.a(2)(e)

[2] This includes all system-related activities, such as procurement, software production, testing and the test infrastructure, storage, transportation, personnel training, operation integration, configuration management, documentation, budgeting, funding, financial management, etc.

[3] DoDI 5000.88, *Engineering of Defense Systems,* §3.5.a(2e)

[4] PRR is required unless waived through the Systems Engineering Plan (SEP) approval process.

- Quality Assurance
- Program Management
- Integrated Logistics Support
- Software Management
- Production Engineering and Planning
- Exit Criteria

In 2014, a DoD standards committee directed creation of the IEEE 15288 series of Industry Systems Engineering Standards that apply to DoD Acquisitions. Specifically, 15288.2 discusses the requirements and the "how to" for technical reviews, which includes specific requirements for a system engineering review. According to IEEE, a PRR reviews the following:

- System documentation with status
- Technical plans
- Program execution and process control
- Risks and risk mitigation
- Program life-cycle cost estimate and schedule

Each technical review, including the PRR, will meet acceptability criteria to hold the review; responsible parties complete preparation actions to conduct the review; appropriate program elements are included in the review; and closure elements are completed. This is part of a complex series of reviews, especially Test Readiness Review (TRR) and Integration Readiness Review (IRR), which contain activities that should be completed by the time a PRR is conducted. Interestingly, these two reviews are omitted from DoDI 5000.88.

EMD Exit Criteria and the Milestone C Review

A PRR, as the final program review before entry into Production and Deployment phase and beginning Low Rate Initial Production (LRIP), should at a minimum address the EMD exit criteria and the Milestone C considerations specified in DoDI 5000.85 as follows:

EMD Exit Criteria

According to DoD 5000.85, §3.11.b(6), MCA, "the EMD Phase will end when :

(a) the design is stable;
(b) the system meets validated capability requirements demonstrated by developmental, live fire (as appropriate), and early operational testing;
(c) manufacturing processes have been effectively demonstrated and are under control;
(d) software sustainment processes are in place and functioning;
(e) industrial production capabilities are reasonably available;
(f) program security remains uncompromised; and
(g) the program has met or exceeds all directed EMD phase exit criteria and Milestone C entrance criteria per the MDA's direction."

The Independent Cost Estimate (ICE) and an Independent Technical Risk Assessment (ITRA) are statutory requirements and will be conducted for Major Defense Acquisition Programs (MDAP) before beginning LRIP[5]; however, these are not included as entrance or exit criteria.

Similar to other Milestone decisions, Systems Engineering (SE), DoDI 5000.88, calls for a major technical program review to consolidate all of the documentation, plans, programmatics, process control, risks, issues, and opportunities, cost, and schedule to be examined in the Milestone C review.

At the Milestone C Review

In DoDI 5000.85, §3.12.b., "The following information will typically be considered at the Milestone C Review:

(1) the results of developmental tests and evaluations and any early operational test and evaluation;
(2) evidence that the production design is stable;
(3) the results of an operational assessment (if conducted);
(4) the maturity of the software;
(5) any significant manufacturing risks;
(6) the status of critical intelligence parameters and intelligence mission data requirements, relative to fielding timelines; and
(7) full funding"

Using the EMD phase exit criteria and Milestone C entrance criteria (above) from DoDI 5000.85, the instruction for MCA, and the documents listed in the References section, we developed the following eight elements that should be addressed as Essential Elements of a PRR. These represent the minimum elements to support program management best practices and sound System Engineering leading to Full Rate Production (FRP).

Essential Elements for Production Readiness

1. Design Stability Met

This addresses "evidence that the design is stable." Design stability, according to IEEE 15288.2, is met by having the "system product baseline" (the design) under proper configuration control and stable to allow for fabrication of hardware and software production and integration during low-rate production. This presumes that the design has been verified and validated for production in a System Verification Review (SVR). The design shows incorporation of open architecture, modular subsystems and components, and use of Design for Manufacturing and Assembly (DFMA) according to best industry standards and practices. The Configuration Management System shows there are minimal drawing changes, with all changes being released on schedule for LRIP. These engineering changes are minimal, meaning the engineering change rate is down to <2-3% of max rate, and design escapes are also minimal and being tracked on weekly basis.

The PRR should include the following metrics to demonstrate design stability:

[5] DOD 5000.85, §3.11.b(6)

- The design is locked, under configuration control, and changes only to meet deficiencies documented during Developmental Test & Evaluation (DT&E) and Initial Operational Test & Evaluation (IOT&E)
- All product level engineering/design requirements have been defined and validated consistent with the specifications detailed in the SEP for LRIP
- Design incorporates open architecture (MOSA), modular subsystems and components, and DFMA according to best industry standards and sound SE practices
- Functional Configuration Audits (FCA) complete
    - All physical and functional interfaces defined, documented, verified, and validated at product, subsystem, item, and component levels both internal and external
    - All subsystems, items, and components perform as required during product DT&E and are integrated into the product
- System Verification Review (SVR) is complete
    - Both product design verification and product design validation have been completed with sufficient evidence provided from testing (design meets the requirements and builds the right product)
    - Documentation accurately reflects the physical configuration for which the test data and any analysis and simulation data are verified

2. Capability Demonstrated by Testing

In demonstrating capability requirements, system-level performance will be verified as satisfactory against the functional baseline and the system will demonstrate the capability to satisfy all Key Performance Parameters (KPP) and Key System Attributes (KSA) thresholds based on available test data, analysis, and inspection. DT&E is the disciplined process of generating substantiated knowledge on the capabilities and limitations of systems, subsystems, components, software, and materiel. It assesses the maturity of technologies, system design, readiness for production, acceptance of government ownership of systems, and readiness to participate in OT&E, and sustainment. DT&E may be conducted by a program or by a designated outside party.

During a PRR, as part of the verified system product baseline documentation review, the system element qualification test planning, conduct, and results will be reviewed. The PRR is conducted after other SE reviews have been successfully completed and closed, such as the TRR, the FCA, the IRR, and the SVR.

A PRR is also conducted after DT&E is complete for all subsystems, and subsystem integrated tests or subsystem test and verifications are complete to include subsystem software tests and subsystem life tests. All hardware and software are tested at operational limits, both threshold and objective.

In addition to testing, Operational Assessments (OAs) may be conducted that often serve as risk reduction events to minimize the risk of finding major issues during IOT&E.[6] DoDI 5000.85 defines OAs as user tests to provide initial assessments of operational effectiveness, suitability, survivability, and the ability to satisfy KPPs and KSAs. Data from OAs may be analyzed and reported as an interim assessment of the

[6] *Test and Evaluation Enterprise Guidebook,* Aug 2022

status of the system's capability and limitations and any risks in meeting operational effectiveness, suitability, and/or survivability.

Conducting a PRR addresses the considerations that during the Milestone C review "the results of developmental tests and evaluations and any early operational test and evaluation" and "the results of an operational assessment(s) show that the product meets validated capability requirements demonstrated by developmental, live fire (as appropriate), and early operational testing." A review of configuration items (CIs) and system-level tests and analyses will be performed with the results verifying and documenting achievement of functional requirements.

The PRR should include the following capability metrics demonstrated through testing[7]:

- TRR is complete and shall confirm that:
  - Test planning, objectives, test methods and procedures, test scope, safety, and readiness for acquirer and supplier development test and evaluation are complete
  - Traceability exists between the planned tests to the applicable program, engineering data, analysis, and certification requirements
- IRR is complete and shall confirm that:
  - The specific hardware and software elements to be used in integrated testing represent a system configuration that has a reasonable expectation of being judged operationally effective and suitable
  - Prior element-level testing produced adequate evidence that the specific hardware and software elements planned for integration testing are sufficiently mature to support successful integration
  - Known anomalies in the specific hardware and software elements to be used in integrated testing are assessed at sufficiently low risk to provide a reasonable expectation of integration test success
  - The tool sets to use for integration testing in the system integration laboratory (SIL) or other equivalent system integration facilities have been verified to provide sufficient operational environment fidelity for integration testing and are under configuration control
- Verification of the achievement of critical technical parameters and KPPs and/or root cause for failures arising from tests with corrective actions should:
  - Provide DT&E data to validate parameters in modeling and simulation (M&S)
  - Assess compatibility in communications and security with legacy systems
  - Provide information for cost, performance, and schedule tradeoffs
  - Report on the program's reliability growth
  - Assess reliability and maintainability performance
- Maturation of the chosen integrated technologies demonstrated by test results
- Readiness for initial OT&E and follow-on OT&E demonstrated by test results
  - Stress the system within the intended operationally relevant mission environment

[7] *Test and Evaluation Enterprise Guidebook,* Aug 2022

- Identify cyber vulnerabilities to hardware and software in components, subsystems, and systems to mitigate early in the lifecycle
- Cybersecurity assessments utilizing the Risk Management Framework (RMF)

3. Manufacturing Maturity Demonstrated

During EMD "manufacturing processes have been effectively demonstrated and are under control" and "any significant manufacturing risks [are] identified and managed." This is accomplished during production of initial engineering/test units in a pilot line environment with manufacturing processes demonstrated as stable and statistically controlled. The requirements for manufacturing processes from DoDI 5000.88, §3.6.c(4) are that manufacturing, producibility, and quality risks are acceptable, supplier qualifications are completed, and any applicable manufacturing processes are or will be under statistical process control. The DoDI is supported by the statements in Clause 6, Table 33, IEEE 15288.2, which calls for manufacturing processes to be stable and demonstrated in a pilot line environment to meet PRR requirements.

The PRR should include the following manufacturing maturity metrics:

- Manufacturing processes for LRIP have been verified on a pilot line
- Process capability data from the pilot line meets targets
- Process capability requirements for LRIP and FRP have been refined based upon pilot line data
- The Supplier Management System shows that program-specific Quality Management Systems are adequate
- Supplier products qualification testing and first article inspection have been completed
- Acceptance testing of supplier products is adequate to begin LRIP
- Availability risks and issues managed for LRIP with long lead procurement initiated for LRIP
- Availability issues addressed to meet FRP builds

The above metrics, which satisfy the requirements from both DoD 5000.88 and IEEE 15288.2, are from the Manufacturing Readiness Level (MRL) process at the MRL 8 level. Conducting an MRA to the MRL 8 criteria will provide the supporting artifacts from the pilot line that show requirements are met. Refer to the *MRL Deskbook 2022* and *MRL Users Guide* for the full MRL 8 set of criteria and metrics.

Additionally, an assessment using the full set of MRL 8 criteria and metrics may assist in addressing the requirements for the Essential Elements 1, 5, 6, 7, and 8 by providing inputs to the criteria in each Element.

4. Software Maturity Demonstrated

Demonstration of software maturity and sustainment involves orchestrating the processes, practices, technical resources, information, and workforce competencies for systems and software engineering; enabling systems to continue mission operations; and allowing software systems to be enhanced to meet evolving threat and capability needs. The EMD exit criteria requires software sustainment processes in place and functioning.

The PRR entrance criteria from IEEE 15288.2 includes having the system product baseline stable and under proper configuration control to enable system hardware fabrication **and system software production** during low-rate production. For the Milestone C Review, the maturity of the software should be sufficient to allow LRIP to begin.

The product software should be tested in simulated operational environments to demonstrate functionality on EMD hardware. The software architecture, design, and Source Lines of Code (SLOC) should be complete. The software security and cybersecurity should be compliant with the NIST risk management guidance. Algorithms and functions, related Measures of Effectiveness (MOEs), and Technical Performance Measures (TPMs) should meet requirements. Embedded product (tactical/system) software should be tested in lab and simulated environments demonstrating that functionality and interface requirements are met.

The PRR should include the following software maturity metrics[8]:

- Software architecture/design and SLOC are complete
- Software FCA per IEEE 15288.2 is complete
- IRR per IEEE 15288.2 is complete
- Algorithms and functions, related MOEs, and TPMs meet requirements
- Embedded product (tactical/system firmware) has been tested in lab and simulated environments and demonstrates functionality and interface requirements are met
- Software runs in full digital/analog environment on test stations with Computer-in-the-Loop (CIL), and/or Hardware-in-the-Loop (HWIL) to include Human Machine Interfaces (HMI) with all requirements met
- Procedures for LRIP software tests are in place
- Software qualification testing in accordance with approved plans is completed
    - Evidence of completed product level testing with installed software should be presented
- Software security and cybersecurity compliant with the NIST risk management guidance and is in place

5. Industrial Capability Available

At this point in the development, "industrial capability" refers to the program's Supply Chain. For the PRR, as required in IEEE 15288.2, the Supply Chain must be ***stable and adequate*** to support planned LRIP and FRP with supplies available.

In the EMD phase, to minimize risks, the industrial base has been analyzed for capacity and capability to support production down to the second and third tier levels. This is accomplished by robust Supply Chain Management processes that have verified for the PRR the industrial capability is in place to support LRIP.

The PRR industrial capability availability metrics should include:

- Assessment of critical second and lower tier supply chain is completed
- Suppliers are available, including multisourcing, where cost effective or necessary to mitigate risk
- Robust requirements flow down processes are in place and verified
- Supplier compliance with program requirements and changes are validated
- Plan for predictive indicators for use in production is updated
- Supply chain is adequate to support LRIP

[8] In 15288.2, the requirements for software are not included in the PRR section, but are included in the requirements for the software FCA, the TRR, and the IRR reviews which are prior to the PRR, assumed to be completed by the PRR.

- All subsystems, hardware, and software, are ready to support LRIP
- All components and items meet cost, quality, and reliability levels and are ready for FRP

6. Program Security

In order to meet the DoDI 5000.85 EMD exit criteria, program security should remain uncompromised. For systems that can operate successfully in the face of threats, cyber threats, and denied environments, engineers will utilize Design for Security and Cyber Resiliency.

The PRR should confirm that System Security Engineering (SSE), COMSEC, cybersecurity, and Program Protection security requirements are implemented into the detailed design in accordance with DoD policies, directives, and system specifications.

The PRR should include the following Design for Security and Cyber Resiliency metrics[9]:

- Cybersecurity and system security requirements meet system performance and product support requirements
- Assessment of the technical baseline, the system architecture, and the design for vulnerabilities is complete
- Technical risk management activities and change management processes address risk identification, analysis, mitigation planning, mitigation implementation, and tracking including both cybersecurity and system security
- Independent threat assessments to technologies, program, and system from appropriate intelligence, counterintelligence, and security entities have been requested
- Automated vulnerability analysis tools and anti-tamper techniques for hardware and software throughout the lifecycle of the system are implemented
- Assured suppliers or appropriate Supply Chain Risk Management countermeasures for system elements that perform mission-critical functions are utilized
- Validated cybersecurity solutions, products, and services are utilized
- Assistance from the Joint Federated Assurance Center to support software and hardware assurance requirements requested when appropriate
- Science & Technology protection and Program Protection, including software and hardware assurance mitigation, are included in contract requirements

One of the Milestone C considerations is the need to address the requisite Intelligence parameters and data requirements, relative to the fielding timelines.[10] These are included in the Lifecycle Mission Data Plan (LMDP), which is the program-level plan that defines how the capability intends to use intelligence data required to operate the system[11]. If required, the LMDP should have been established in the Materiel Solutions Analysis (MSA) phase with the assistance of acquisition and intelligence analysts to provide input to the program in the development of LMDP[12].

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[9] DoDI 5000.83, *Technology And Program Protection To Maintain Technological Advantage*, Jul 2020

[10] DoDI 5000.85

[11] *LMDP Guidebook and Templates*, ver. 3.1, Apr 2014

[12] DoDD 5250.01, *Management of Intelligence Mission Data (IMD) in DoD Acquisition,* Aug 2017, §4.c.

The PRR should include the following LMDP metrics:

- The LMDP is up to date
- The LMDP aligns with current fielding timelines

7. Product Support Plans

Program final designs for Product Support (PS) elements, including lifecycle logistics, should be integrated into a comprehensive support package that is documented in a Product Support Strategy (PSS) and contained in the Life Cycle Support Plan (LCSP). According to DoDI 5000.85, the program will demonstrate PS performance through appropriate verification means that satisfy the sustainment requirements within the MDA-approved program goals previously established. This requires LRIP fielding requirements to be demonstrated including PS operations, maintenance, training systems and support. The PRR confirms that the LCSP contains adequate planning applicable to production for sustainment.

In accordance with DoDI 5000.91, *Product Support Management for the AAF,* Nov 2021, the LCSP is the primary program reference governing Operations & Support (O&S) planning and execution from program inception to disposal. An approved LCSP is required for all covered systems[13] and includes updates on program sustainment development efforts and schedules based on current budgets, test, and evaluation results; and firm supportability design features. The LCSP is the principal document establishing the system's product support planning and sustainment, pursuant to Section 2337 of Title 10, U.S.C.

The PRR should include the following metrics as part of the LCSP:

- A complete and comprehensive PSS
- Key sustainment KPPs, KSAs, and other appropriate sustainment metrics are met
- A life cycle cost estimate for the system is complete and approved
- Product Support Business Case Analysis (PS BCA) is up to date
- Identification of affordability constraints and key cost factors affecting O&S costs and proposed mitigation plans are complete; mitigation is on going
- Sustainment risks, including Supply Chain Risk Management (SCRM); diminishing manufacturing sources and material shortage (DMSMS) risk; counterfeit risk; and Parts, Materials, and Processes (PM&P) risks, are managed and mitigated
- Engineering and design procedures to support cost-effective sustainment of the system including DMSMS resilience is established
- Software support requirements are met
- A product support technical data and intellectual property (IP) management plan is complete
- Major maintenance with overhaul requirements plans for the system's life cycle are in place
- A plan to leverage enterprise opportunities across programs and DoD Components is in place

[13] 10 USC §4324(d)5, The term "covered system" means a major defense acquisition program as defined in section 4201 or an acquisition program or project that is carried out using the rapid fielding or rapid prototyping acquisition pathway.

8. Program Funding

One of the final considerations at the Milestone C review is the funding status of the program. The Program and the DoD Component must balance the requirements and cost based on the available funding. This comes from the DoD Component Cost Position (CCP), which is derived from the DoD Component Cost Estimate and the Program Office Estimate per DoD Component policy. Consideration must be given to both near-term development and production costs and the long-range operations and sustainment costs of deployed systems. This comprises the full funding requirements to be confirmed at the PRR. The CCP should capture all program costs requiring funding and address all of the required content of an ICE.

The PRR should review the CCP updated cost estimate based on the following areas for full funding[14]:

- All costs of development
- Procurement
- Military construction
- Operations and support
- Disposal
- Trained manpower to operate
- Sufficient manpower to maintain and support the program or subprogram upon full operational deployment without regard to funding source or management control

At the Milestone C Review, the MDA will direct that either the CCP or ICE be used as the acquisition program baseline. A full funding certification statement in the Acquisition Decision Memorandum (ADM) is required at Milestones A and B and at the LRIP and FRP decisions.[15]

Summary

The EMD phase exit criteria and Milestone C entrance criteria from DoDI 5000.85, the instruction for Engineering of Defense Systems, and the documents listed in the References section, were used to develop the eight Essential Elements for a Production Readiness Review. These represent the minimum elements to support program management best practices and sound System Engineering leading to Full Rate Production.

Observations

- While targeted at MCAs, the Essential Elements for a PRR described in this paper can be readily tailored to apply to Mid Tier Acquisitions (MTAs) and Urgent Operational Needs (UONs) as a means to demonstrate the readiness for production.
- The meaning of the words production and manufacturing are used synonymously in many uses and references; however, the term “production readiness” is not synonymous with the term “manufacturing readiness” in assessment of a system. Production readiness requires

[14] DoDI 5000.73, *Cost Analysis Guidance and Procedures,* Mar 2020*,* states that an ICE includes these items for a full life-cycle cost estimate of a program.
[15] DoDI 5000.73, §3.4.b(12a)

understanding the maturity of all of the activities to design, manufacture, assemble, integrate, test, deploy, and sustain a system that meets cost, schedule, and performance requirements. Whereas, manufacturing readiness refers to the ability (processes, procedures, and techniques) to build the system.

Conclusions

In order to proceed into the Production and Deployment Phase, programs must meet or exceed all EMD phase exit criteria and Milestone C entrance criteria as directed by the MDA and confirmed during the PRR.

Additionally, although not included as "exit criteria," the independent assessments of an ICE and an ITRA, which are statutory requirements, will be conducted for MDAPs before beginning LRIP. These assessments will provide independent production cost and identification of program risks.

Any additional customization or tailoring of the program requirements or the Milestone C entrance criteria, per the MDA's direction, should be met or exceeded. This is consistent with the IEEE 15288.2 requirement to meet all exit and entrance criteria for SE reviews prior to Milestone C.

We developed the eight Essential Elements of a PRR, including the criteria and metrics for each element. These elements address all of the exit criteria for EMD, all of the review topics for the Milestone C, and are consistent with the requirements from IEEE 15288.2 for a PRR. The discussion and evaluation of the PRR Essential Elements in this paper demonstrates that Manufacturing Readiness Assessments, including using the MRL process, are not sufficient as the final program review prior to Milestone C decision.

References:

1. IEEE 15288.2, *Technical Reviews and Audits on Defense Programs*, Nov 2014
2. *Test and Evaluation Enterprise Guidebook*, Aug 2022
3. *DoD MRL Deskbook*, Oct 2022
4. DoDI 5000.85, *Major Capability Acquisition*, Aug 2020
5. DoDI 5000.83, *Technology And Program Protection To Maintain Technological Advantage*, Jul 2020
6. DoDI 5000.91, *Product Support Management for the AAF*, Nov 2021